AD-A047 276   AIR FORCE AERO PROPULSION LAB WRIGHT-PATTERSON AFB OHIO   F/G 11/4
DETERMINATION OF THE EFFECT OF PRETEST RATINGS OF JET FUEL THER--ETC(U)
JUN 77

UNCLASSIFIED   AFAPL-TR-77-53   NL

| OF |
ADA047276

END
DATE
FILMED
| -78
DDC

⑭ AFAPL-TR-77-53

⑫
B.S.

⑥

DETERMINATION OF THE EFFECT OF PRETEST RATINGS OF JET FUEL THERMAL OXIDATION TESTER TUBES ON POST-TEST RATINGS USING THE TUBE DEPOSIT RATER.

FUELS BRANCH
FUELS AND LUBRICATION DIVISION

⑪ JUN 77   ⑫ 50 p.

TECHNICAL REPORT AFAPL-TR-77-53
⑨ Final Report, Jun 975 — Jun 77.

⑯ 3048

⑫ 05

Approved for public release; distribution unlimited.

AIR FORCE AERO PROPULSION LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
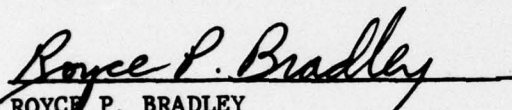WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433
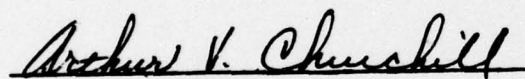
D D C
RECEIVED
DEC 6 1977
B

011 570

This technical report has been reviewed and is approved for publication.

ROYCE P. BRADLEY
Project Engineer

FOR THE COMMANDER

ARTHUR V. CHURCHILL, Chief
Fuels Branch
Fuels and Lubrication Division

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFAPL-TR-77-53	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* DETERMINATION OF THE EFFECT OF PRETEST RATINGS OF JET FUEL THERMAL OXIDATION TESTER TUBES ON POST-TEST RATINGS USING THE TUBE DEPOSIT RATER		5. TYPE OF REPORT & PERIOD COVERED Final Report June 1975 - June 1977
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Lt. Larry Tackett Royce P. Bradley		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Aero Propulsion Laboratory Air Force Systems Command Wright-Patterson Air Force Base, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS P.E. 62203F W.U. No. Proj. 3048 30480523 Task 304805
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Aero Propulsion Laboratory Fuels Branch (SFF) Wright-Patterson AFB, OH 45433		12. REPORT DATE June 1977
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Fuel Thermal Stability   Fuel Degradation Deposits
Jet Fuel Thermal Oxidation Tester
JFTOT
Deposit Rating Techniques
Tube Deposit Rater

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The Jet Fuel Thermal Oxidation Tester (JFTOT) is used by the Air Force to determine the thermal stability of JP-4 and JPTS type fuels. A device called the Tube Deposit Rater (TDR) has been proposed as a means of evaluating the deposits formed on JFTOT tubes. Concern has existed about the need to account for the pretest condition of the test tubes. The effect of pretest ratings is discussed in the report and a method is proposed for improving results by accounting for the pretest condition of the tubes.

DD FORM 1473   1 JAN 73   EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

FOREWORD

This report contains the results of an effort to determine the effect of pretest tube rating values upon the post-test tube rating values, as determined by the ALCOR Mark 8A Tube Deposit Rater (TDR). The work was performed in the Fuels Branch of the Air Force Aero Propulsion Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio under Project 3048, Task 304805, Work Unit 30480523. The effort was conducted by Lt. Larry P. Tackett and Mr. Royce P. Bradley during the period June 1975 to June 1977.

TABLE OF CONTENTS

v

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont'd)

LIST OF TABLES

SECTION I

INTRODUCTION

The concept of determining fuel thermal stability is one of paramount importance not only to the U.S. Air Force, but also to the commercial airlines and engine manufacturers. This importance can be related to today's jet turbine engines and their use of jet fuel as a cooling medium as well as for combustion purposes.

The jet fuel is routinely used in heat exchangers to absorb heat from the avionic systems, the environmental control system, and the engine lubricant. In some cases, the fuel is used to cool the structure of super-sonic aircraft. Should the fuel not have adequate thermal stability, it may form deposits in fuel lines, heat exchangers, or filters. Plugging of any of these units could result in a decrease in operating efficiency, or a system failure.

As the fuel is used for noncombustion applications, it may reach 250-325°F routinely. Obviously, advance knowledge of whether or not a fuel will be thermally stable at those temperatures is necessary. The determination of fuel thermal stability has been accomplished for more than fifteen years by use of the Coordinating Research Council-American Society of Testing and Materials (CRC-ASTM) Fuel Coker (ASTM D 1660). This testing device subjects the fuel to elevated temperatures over a heated tube and through a filter. Thermally unstable fuel will form deposits on the tube and/or cause plugging of the filter. A newer device

1

used to accomplish the same test is the Jet Fuel Thermal Oxidation
Tester (ASTM D 3241), or JFTOT. Compared to the Fuel Coker, the JFTOT
uses less fuel, requires less time to conduct the test, and is more
precise.

Both test devices use a heated aluminum tube, which the fuel is
passed over, as the basis of the test. Following the test, the tubes
are removed and "rated" as to the amount of deposits formed.

For many years, these tubes have been rated visually. The visual
rating is accomplished by using a light box that contains three incan-
descent light bulbs, a non-reflecting interior, and holders for the ASTM
Color Standards and tubes. A tube is placed in a holder and inserted
into the light box. The ASTM Color Standards are then compared to the
tube and the rater determines which of the Color Standards the tube
matches best. This technique is very subjective in nature and different
raters have been known to give significantly different ratings to the
same tube.

Since 1972, another method, the ALCOR Mark 8A Tube Deposit Rater
(TDR), has been available that affords a less subjective determination of
JFTOT tube deposits. This method is based upon light reflectance
principles and uses a photocell to measure the light reflected from the
tube surface. The output of the photocell is indicated on a meter having
50 divisions.

A tube is rated by inserting it in the TDR and moving the photocell along the length of the tube until the point of maximum deposit is found. This is accomplished with the tube stationary or spinning, and the photocell moved up and down by the operator. At the Air Force Aero Propulsion Laboratory, the ALCOR Mark 8A TDR has been modified. The TDR is coupled to an X-Y plotter, and as a motorized drive moves the photocell along the length of the tube, a "picture" of the TDR values all along the tube is produced (see Figure 1). This plot of TDR values versus distance along the tube is used to identify the location of maximum TDR value, as well as any TDR value for a given location on the tube.

Another area of interest is with regards to the relationship between the before test (clean tube) TDR rating and the after test (deposit on tube) rating. Specifically, it is important to know what, if any, effect the before test rating has on the after test rating. Put another way; does the surface (rough or smooth) of the clean tube in any way affect the after test TDR rating. If there is no effect, then the after test rating would be taken as the deposit rating. Should the surface of the clean tube affect the final rating, the final TDR rating will have to be adjusted (e.g., subtract initial rating) to give the true deposit rating.

The work discussed herein is concerned with determining the relationship, if any, between the initial and final TDR ratings.

3
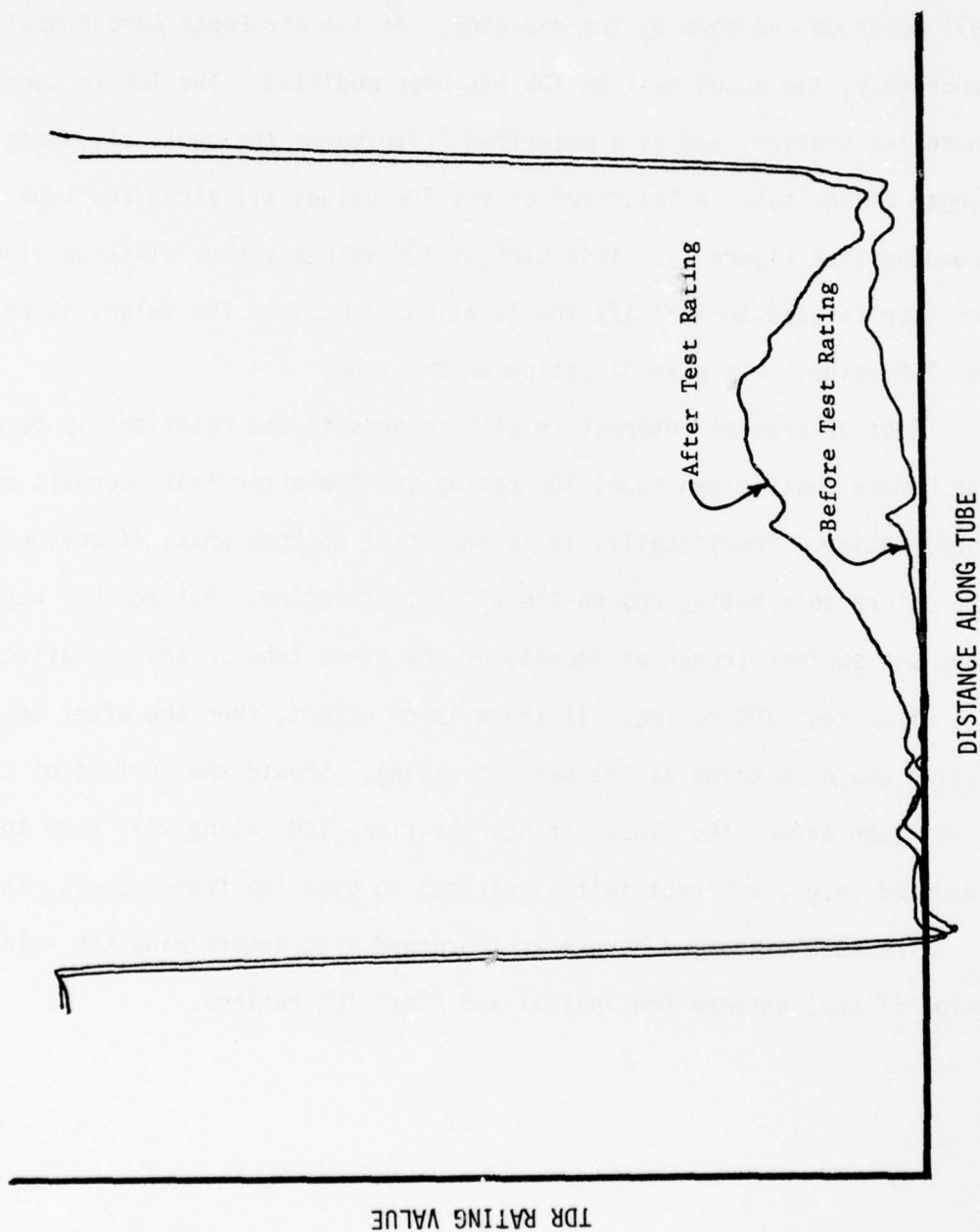
Figure 1. Typical Plot of TDR Values Along a JFTOT Tube.

SECTION II

APPROACH

Two fuels were selected for the test program. One fuel was a JP-4 type fuel identified as Survey 12 (Reference 1). The other fuel was a low quality JP-4 type fuel identified as AFFB-16-73 (see Appendix A). Two JFTOT test devices were used for the tests. All tests were run for 150 minutes at a pressure of 3.43 MPa.

The JFTOT tubes were selected based upon their initial TDR ratings. Since the objective of the tests was to determine the effect of initial tube ratings on final tube ratings, tubes were selected that had various initial ratings. Following each test, the tube was given a final TDR rating. The post-test rating for each tube was done on the same plot as was the pretest rating, thus affording a means of direct comparison between the two ratings. A typical rating plot is shown in Figure 1. The maximum rating and its location as well as the deposit rating value anywhere along the tube can be readily determined from the plot.

Several parameters were evaluated to accomplish the desired comparison between initial and final ratings. Those parameters obtained directly from the plots included:

1. Maximum TDR value

2. Location of maximum TDR value

3. TDR value at tube position 38.7 cm (this point is the hottest point on the tube).

5

Another set of parameters was evaluated that required a direct comparison between the initial and final ratings. These parameters were all based upon the difference (in TDR units of measure) between the initial and final rating for each tube. For example, Rating Difference (delta R) = (final value - initial value) at any point along the tube.

The delta R parameters measured were the same as previously mentioned for the regular TDR ratings (viz.; maximum delta R, location of maximum delta R, and delta R at tube position of 38.7) with one exception. The value of delta R was determined at each centimeter along the tube and plotted versus tube position (see Figure 2). By means of a least squares curve fitting technique, the equation of the delta R versus distance curve was determined. This curve represents the difference in reflectance of the deposit formed on the tube by the fuel. The delta R equation was integrated to determine the area under the curve. A comparison of the areas for the tubes offered another means of relating initial and final tube reflectance ratings.
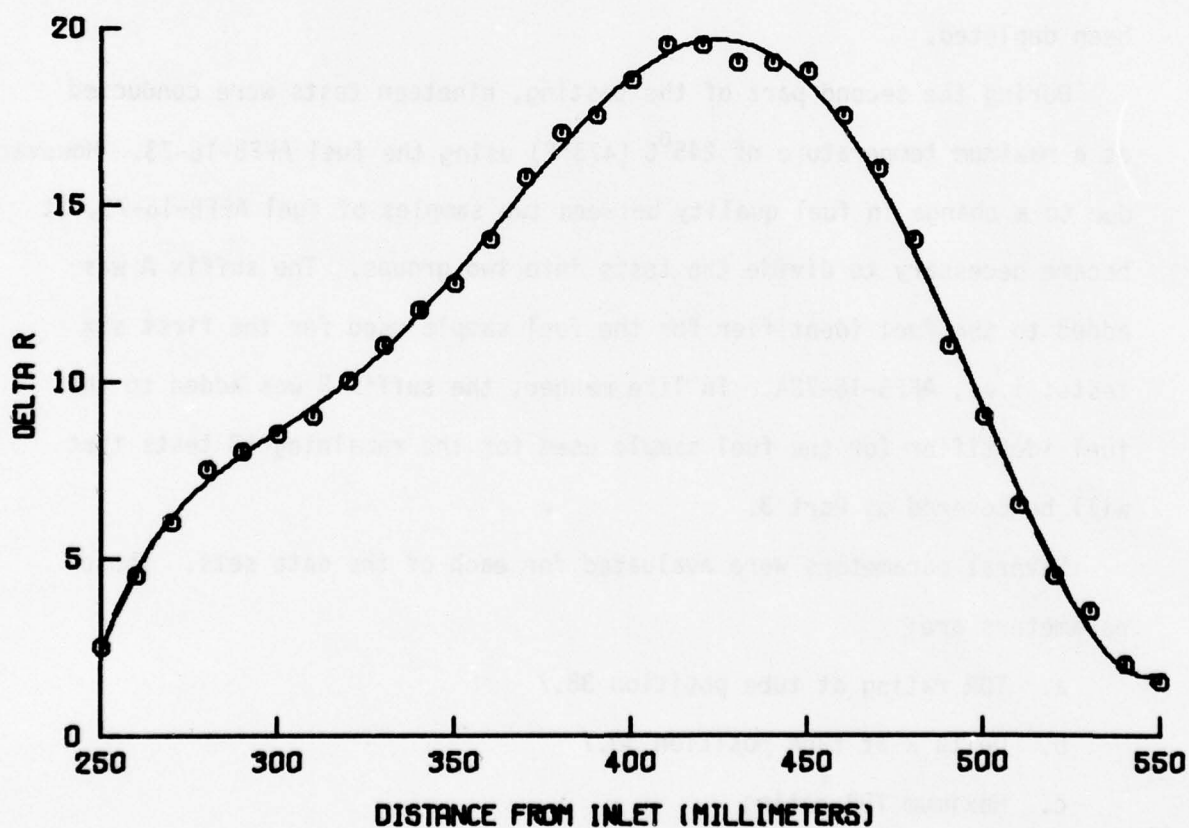
FIGURE 2. DELTA R AS A FUNCTION OF LOCATION

SECTION III

RESULTS OF CURRENT TESTING

1. GENERAL COMMENTS

Presentation of the results will be divided into three parts. The first part will deal with the data obtained from JFTOT tests using the Survey 12 fuel. A total of 12 tests were conducted at a maximum temperature of $275^{\circ}C$ ($527^{\circ}F$). Subsequent to completion of the tests, it was necessary to change test fuels since the supply of Survey 12 fuel had been depleted.

During the second part of the testing, nineteen tests were conducted at a maximum temperature of $245^{\circ}C$ ($473^{\circ}F$) using the fuel AFFB-16-73. However, due to a change in fuel quality between two samples of fuel AFFB-16-73, it became necessary to divide the tests into two groups. The suffix A was added to the fuel identifier for the fuel sample used for the first six tests; i.e., AFFB-16-73A. In like manner, the suffix B was added to the fuel identifier for the fuel sample used for the remaining 13 tests that will be covered as Part 3.

Several parameters were evaluated for each of the data sets. These parameters are:

a. TDR rating at tube position 38.7

b. Delta R at tube position 38.7

c. Maximum TDR rating

d. Delta R at location of maximum TDR rating

8

     e.   Location of maximum TDR rating

     f.   Maximum delta R

     q.   Location of maximum delta R

     h.   Area between pre and post-test curves.

2.   SURVEY 12 FUEL

The data from the tests conducted using the Survey 12 fuel are presented in Table 1. In addition, the minimum value, maximum value, average value, and standard deviation are also presented. The values shown on the bottom line in Table 1 were obtained by dividing each average value by the corresponding standard deviation and multiplying the quotient by 100. The percentage that results provides a value that makes a comparison amongst the different parameters much easier.

Plots were made of the six parameters listed above versus the initial ratings to show the relationship between initial and final ratings. These plots are presented in Figures 3 through 7. The lines through the data were determined using a linear-least-squares method. The resulting regression equations are shown on each plot along with the correlation coefficient.

In reviewing the plots, it should be remembered that the values of delta R were obtained by subtracting the initial values from the final values. Thus, if this approach accounts for the variation in initial ratings, then the regression lines on those plots with delta R as the dependent variable should have a slope close to zero. The other plots should have lines with slopes close to one.

TABLE 1

DATA FOR FUEL SURVEY

TEST NR.	RATING AT POSITION 38.7			RATING AT LOCATION OF MAXIMUM RATING				RATING AT LOCATION OF MAXIMUM DELTA R			AREA BETWEEN PRE AND POST-TEST CURVES
	PRE	POST	DELTA R	PRE	POST	DELTA R	LOCATION	PRE	DELTA R	LOCATION	
2417	1.1	14.6	13.5	1.1	14.8	13.7	40.0	1.1	13.7	39.5	-
2435	4.7	20.3	15.6	4.8	21.1	16.3	45.1	3.1	17.2	41.0	273
2441	-1.6	11.3	12.9	-1.6	11.3	12.9	38.7	-1.6	12.9	38.7	242
2445	2.0	10.5	8.5	6.8	13.0	6.2	45.3	2.1	8.7	39.0	159
2452	0.7	12.3	11.6	3.6	13.4	9.8	36.0	-0.3	13.0	41.0	203
2453	0.3	15.7	15.4	1.0	17.3	16.3	41.2	1.0	16.3	41.2	267
2455	-0.4	8.6	9.0	1.8	10.3	6.5	42.0	-0.4	9.0	38.7	173
2456	5.7	18.3	12.6	5.7	18.8	13.1	39.2	3.2	13.7	41.0	217
2462	0.8	13.9	13.1	1.3	14.5	13.2	40.0	0.6	13.4	37.6	271
2466	-1.2	16.8	18.0	0.8	17.8	17.0	32.8	-1.0	18.2	37.5	361
2469	-3.9	7.0	10.9	-3.0	7.9	10.9	35.4	-3.1	11.0	36.0	216
2471	0.3	14.7	14.4	0.9	15.6	14.7	40.3	0.4	14.8	39.5	260
MINIMUM VALUE	-3.9	7.0	8.5	-3.0	7.9	6.2	32.8	-3.1	8.7	36.0	159
MAXIMUM VALUE	5.7	20.3	18.0	6.8	21.1	17.0	45.3	3.2	18.2	41.2	361
AVERAGE ($\bar{X}$)		13.7	13.0		14.7	12.7	39.7		13.5	39.2	240
STD. DEVIATION (S)		3.9	2.7		3.8	3.3	3.7		2.9	1.7	56
($\bar{X}$ ÷ S) (%)		28.7	21.1		25.8	26.1	9.3		21.8	4.2	23

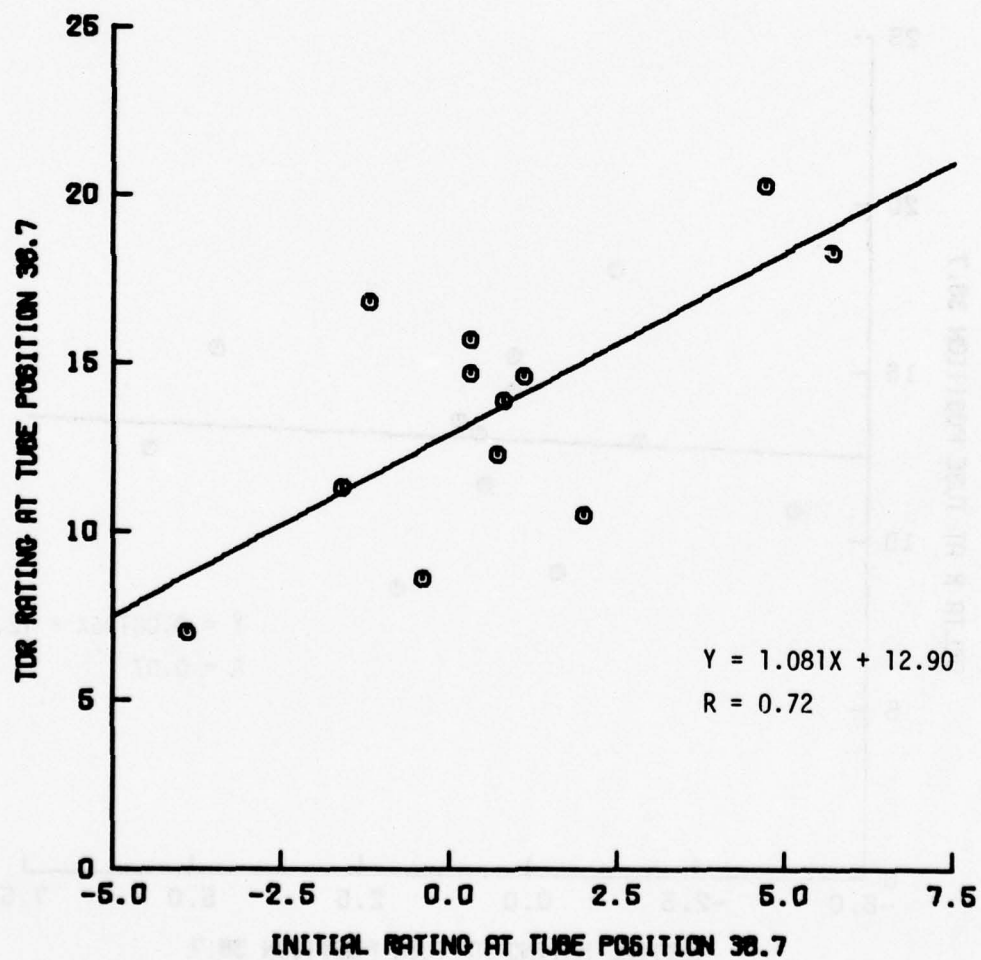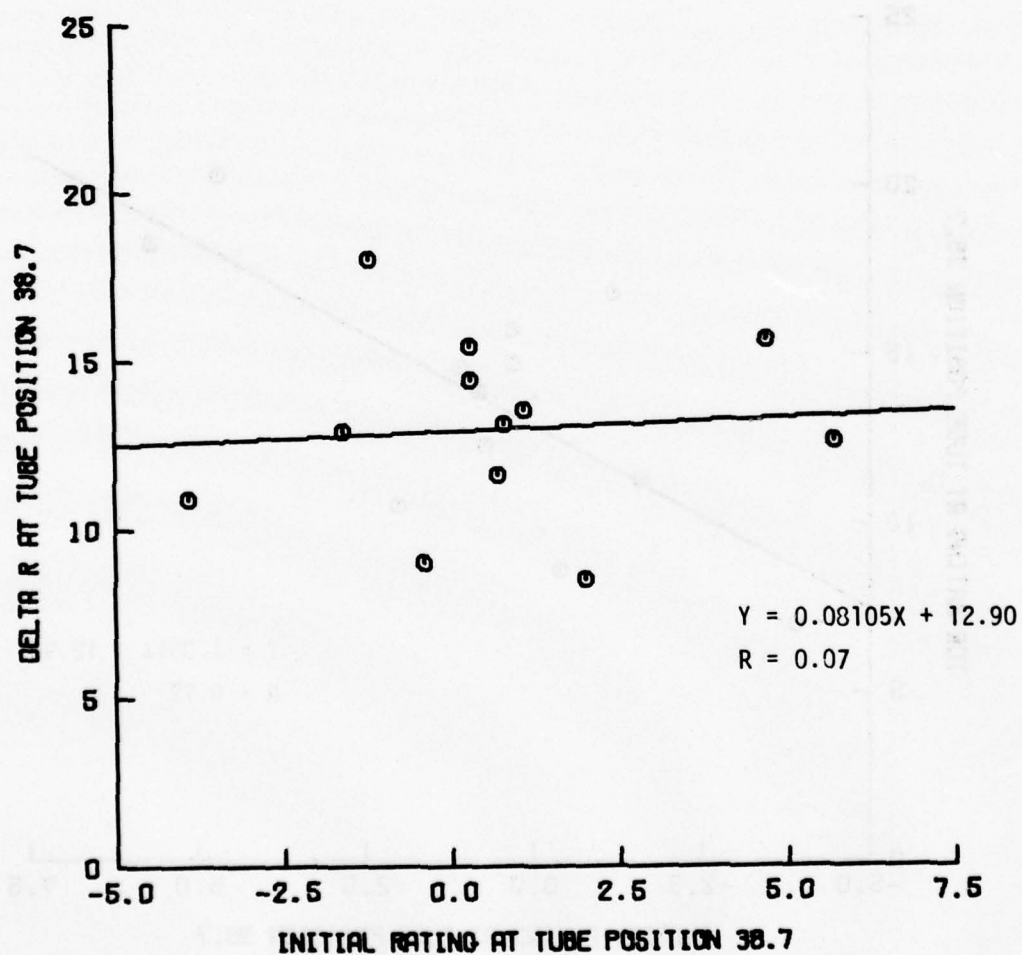FIGURE 3. EFFECT OF INITIAL RATING ON RATING AT POSITION
38.7 (SURVEY 12)

11

FIGURE 4. EFFECT OF INITIAL RATING ON DELTA R AT TUBE
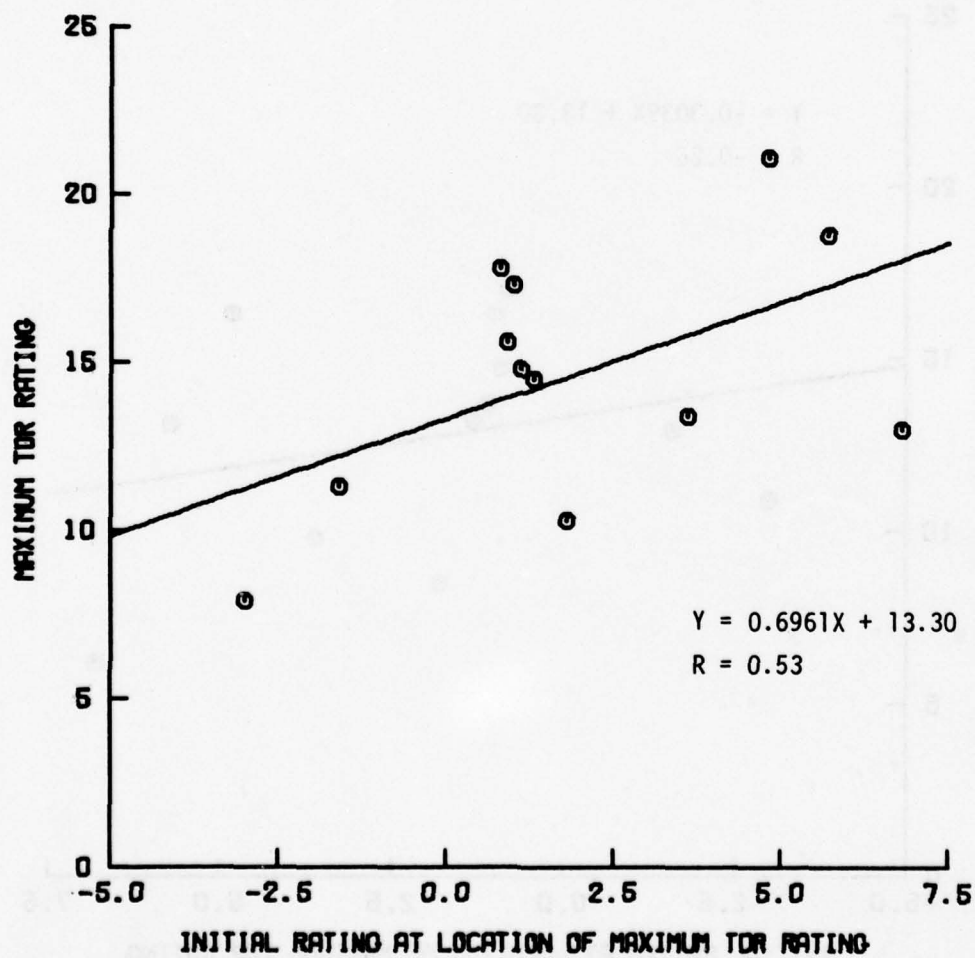POSITION 38.7 (SURVEY 12)

12

FIGURE 5. EFFECT OF INITIAL RATING ON MAXIMUM RATING (SURVEY 12)

13

FIGURE 6.   EFFECT OF INITIAL RATING ON DELTA R AT LOCATION OF
MAXIMUM RATING (SURVEY 12)

14

FIGURE 7. EFFECT OF INITIAL RATING ON MAXIMUM DELTA R (SURVEY 12)

15

3. AFFB-16-73A FUEL

The data from the tests conducted using the fuel identified as AFFB-16-73A are presented in Table 2. The same parameters are shown as were included for the Survey 12 fuel. Plots of the data are shown in Figures 8 through 12. The data collected for this fuel covers a very narrow range of initial tube ratings. This resulted from the limited availability of tubes at the time the tests were conducted.

4. AFFB-16-73B FUEL

The data from the tests conducted using the fuel identified as AFFB-16-73B are presented in Table 3. Plots of the data are shown in Figures 13 through 17.

TABLE 2

DATA FOR FUEL AFFB-16-73A

TEST NR.	RATING AT POSITION 38.7			RATING AT LOCATION OF MAXIMUM RATING				RATING AT LOCATION OF MAXIMUM DELTA R			AREA BETWEEN PRE AND POST-TEST CURVES
	PRE	POST	DELTA R	PRE	POST.	DELTA R	LOCATION	PRE	DELTA R	LOCATION	
2744	-0.7	15.0	15.7	-0.3	16.0	16.3	44.0	-1.0	16.8	42.0	360
2745	0.2	15.5	15.3	0.7	17.0	16.3	44.7	0.2	16.3	43.0	303
2747	-1.1	14.3	15.4	-0.2	16.4	16.2	42.5	-0.3	16.8	42.5	302
2748	-0.6	15.0	15.6	0.2	17.5	17.3	44.0	0.2	17.3	44.0	333
2754	-1.9	17.0	15.1	2.0	18.8	16.8	42.5	2.0	16.8	42.5	351
2755	-0.9	16.1	17.0	-0.1	17.2	17.3	41.7	-0.3	17.3	42.0	410
MINIMUM VALUE	-1.9	14.3	15.1	-0.3	16.0	16.2	41.7	-1.0	16.3	42.0	302
MAXIMUM VALUE	0.2	17.0	17.0	2.0	18.8	17.3	44.7	2.0	17.3	44.0	410
AVERAGE ($\bar{X}$)		15.5	15.7		17.2	16.7	43.2		16.9	42.7	343
STD. DEVIATION (S)		1.0	0.7		1.0	0.5	1.2		0.4	0.8	41
($\bar{X} \div S$) 100 (%)		6.2	4.3		5.7	3.1	2.7		2.2	1.8	12

FIGURE 8.   EFFECT OF INITIAL RATING ON RATING AT POSITION
38.7 (AFFB-16-73A)

18

FIGURE 9. EFFECT OF INITIAL RATING ON DELTA R AT TUBE POSITION
38.7 (AFFB-16-73A)

19
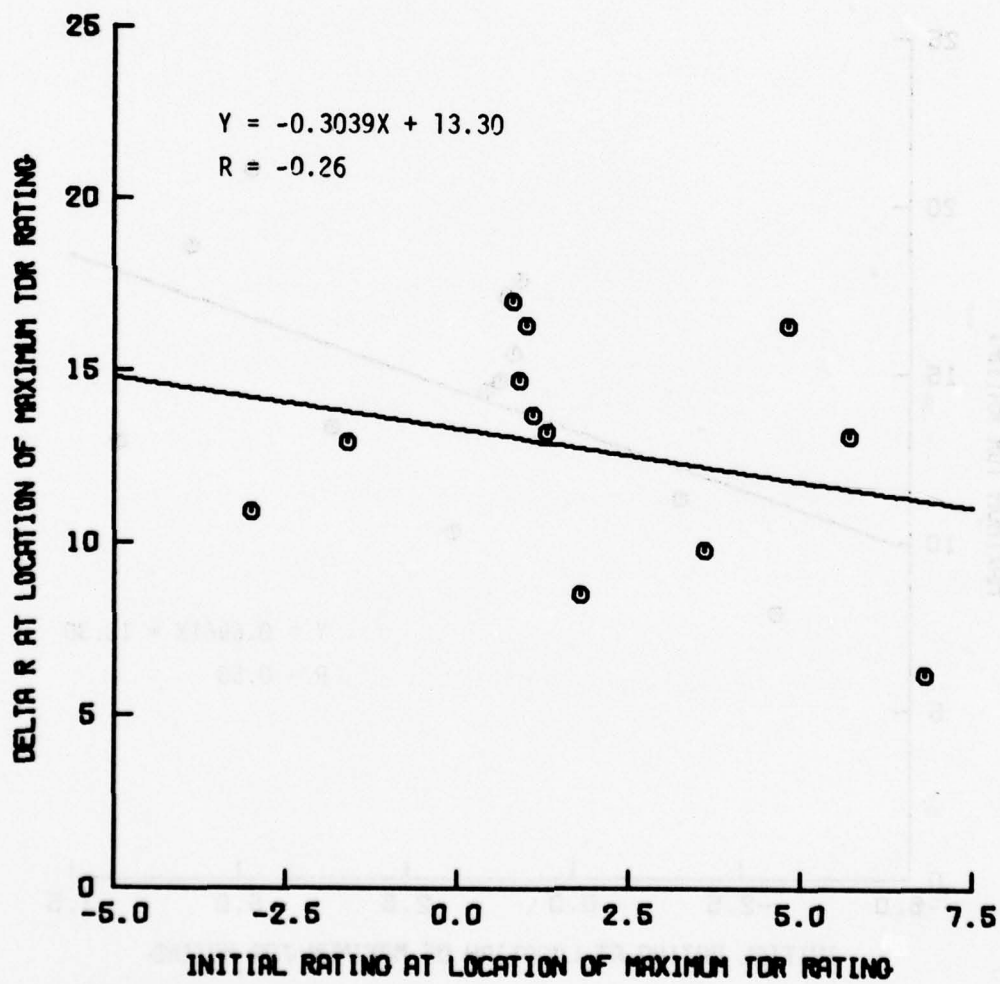
FIGURE 10.   EFFECT OF INITIAL RATING ON MAXIMUM RATING (AFFB-16-73A)

20

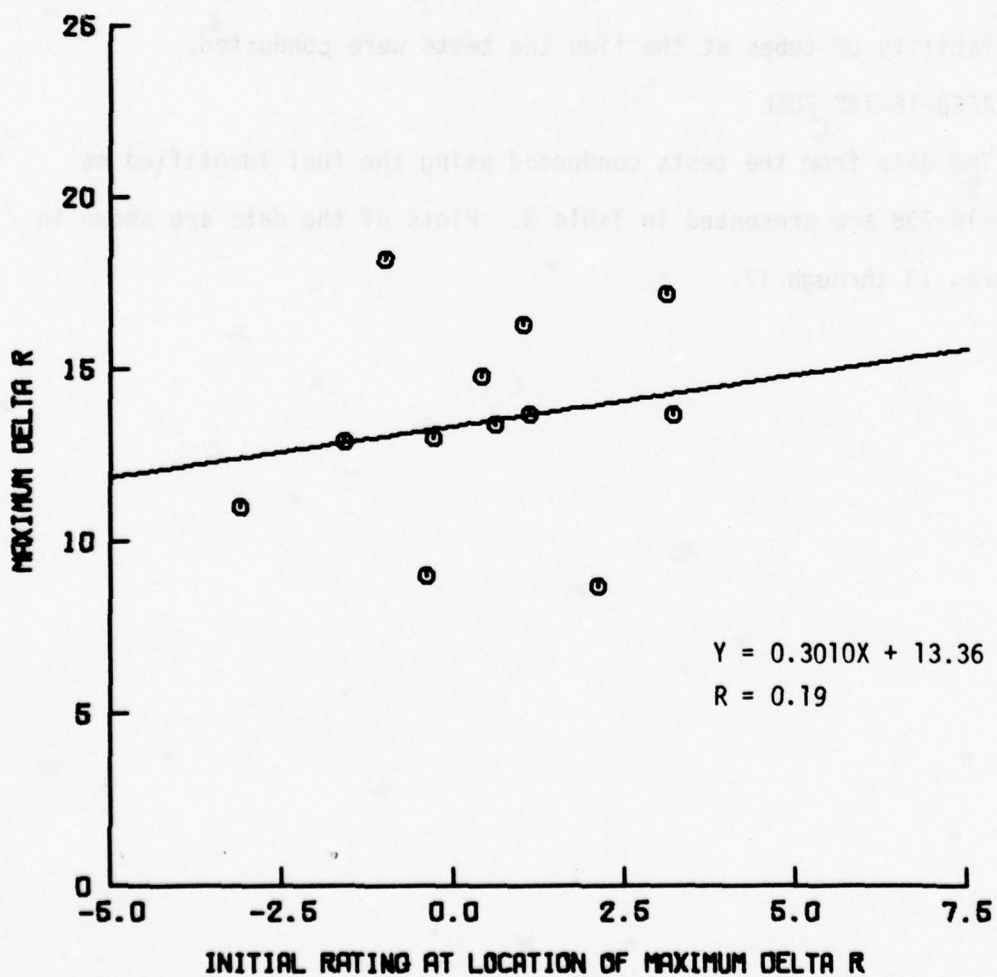FIGURE 11.   EFFECT OF INITIAL RATING ON DELTA R AT LOCATION OF
MAXIMUM RATING (AFFB-16-73A)

21

$$Y = -0.04204X + 16.89$$
$$R = -0.11$$

FIGURE 12.   EFFECT OF INITIAL RATING ON MAXIMUM DELTA R (AFFB-16-73A)

22

TABLE 3

DATA FOR FUEL AFFB-16-73B

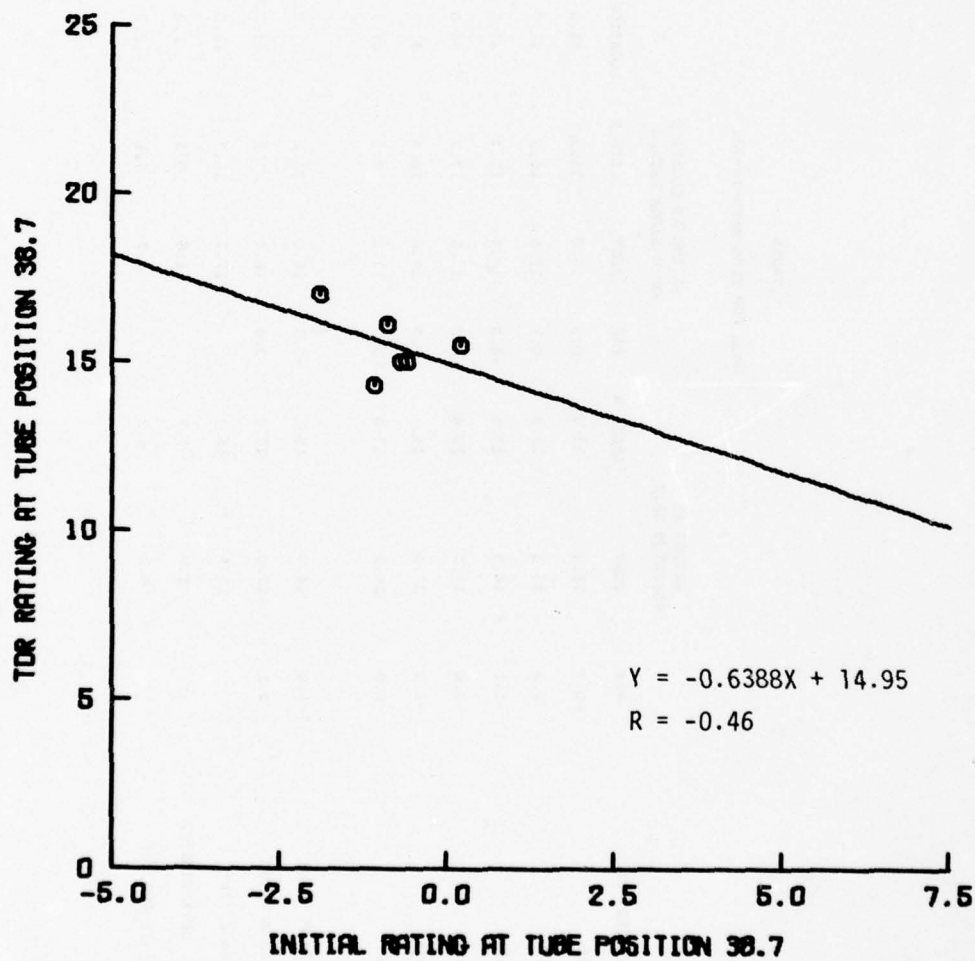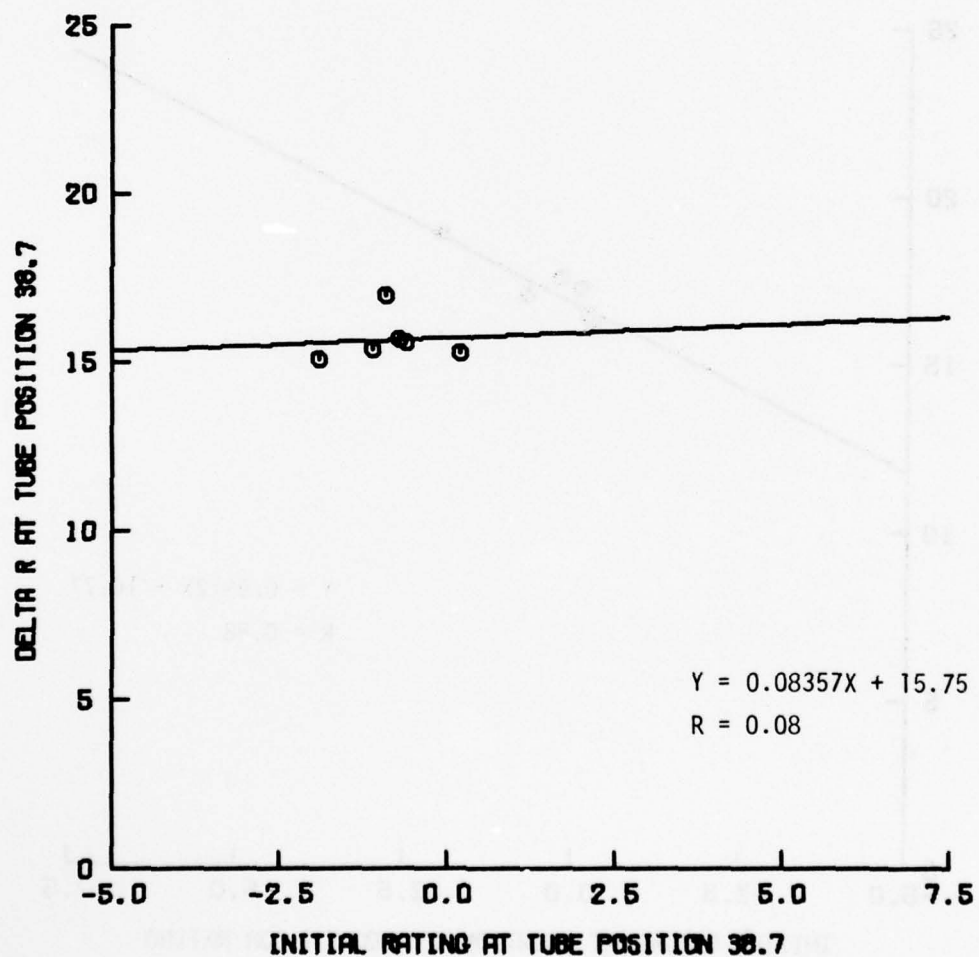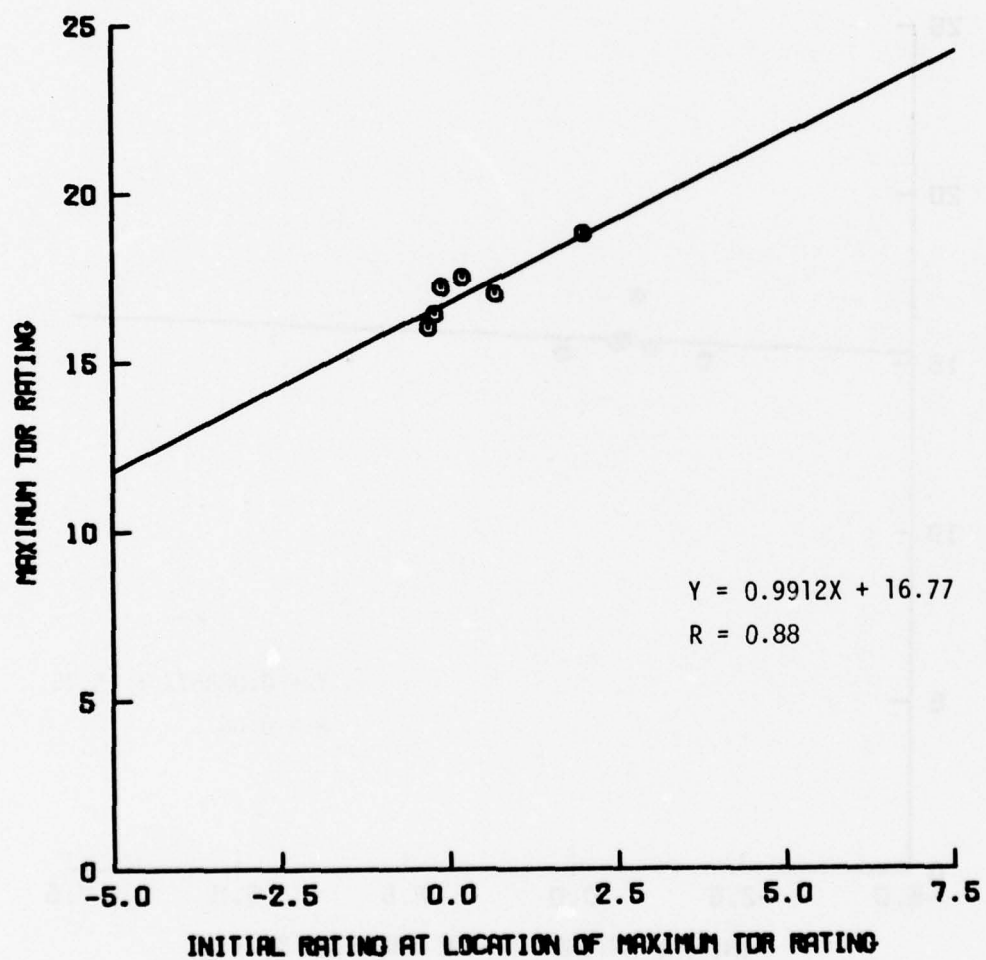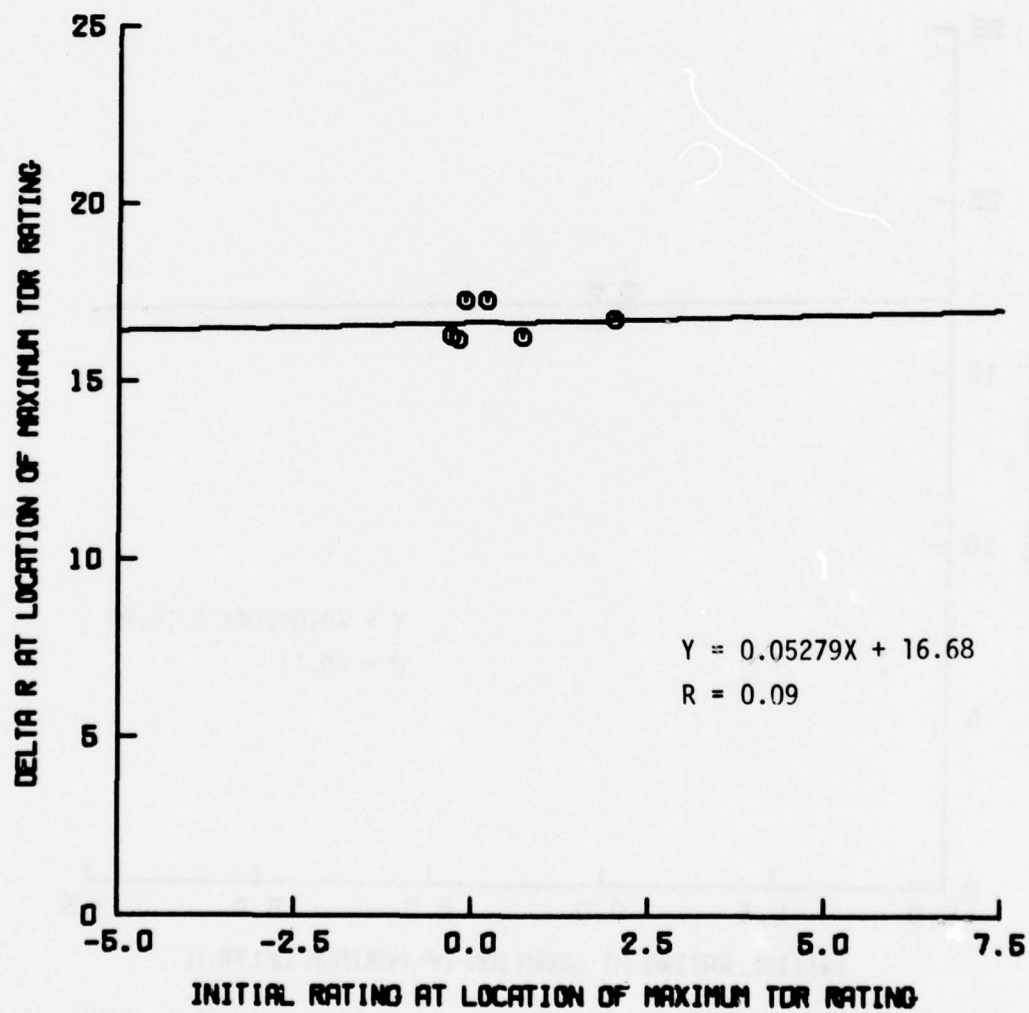| TEST NR.	RATING AT POSITION 38.7			RATING AT LOCATION OF MAXIMUM RATING				RATING AT LOCATION OF MAXIMUM DELTA R			AREA BETWEEN PRE AND POST-TEST CURVES
	PRE	POST	DELTA R	PRE	POST	DELTA R	LOCATION	PRE	DELTA R	LOCATION	
2756	-0.9	6.6	7.5	0.3	9.0	8.7	46.0	-0.7	9.4	42.5	165
2757	-0.8	8.1	8.9	1.7	10.2	9.5	44.5	0.0	9.8	44.0	149
2758	-1.0	5.5	6.5	-0.8	7.0	7.8	44.5	-0.9	7.8	44.0	142
2759	0.6	9.4	8.8	1.0	11.4	10.4	43.5	0.7	10.6	43.0	174
2761	-0.8	6.1	6.9	-0.5	7.3	7.8	42.5	-1.0	8.0	42.0	135
2762	-1.0	5.3	6.3	-0.3	7.0	7.3	44.0	-0.6	7.5	43.5	136
2763	0.1	7.4	7.3	0.5	9.1	8.6	41.5	0.0	9.0	41.0	139
2764	0.9	9.3	8.4	1.3	10.6	9.3	43.0	1.3	9.4	43.5	153
2769	-1.0	8.0	9.0	-1.6	9.1	10.7	43.3	-1.5	10.7	43.5	147
2776	-3.8	1.7	5.0	-1.9	3.6	5.5	47.4	-1.8	6.6	43.0	114
2777	-2.8	5.0	7.8	-2.8	6.3	9.1	43.0	-2.9	9.2	42.5	170
2778	-0.3	7.9	8.2	0.0	9.9	9.9	41.8	-0.1	10.0	42.0	189
2779	-2.6	4.6	7.2	-2.5	6.4	8.9	43.5	-2.7	9.1	43.0	160
MINIMUM VALUE	-3.8	1.7	5.0	-2.8	3.6	5.5	41.5	-2.9	6.6	41.0	114
MAXIMUM VALUE	0.9	9.4	9.0	1.7	11.4	10.7	47.4	1.3	10.7	44.0	189
AVERAGE ($\bar{X}$)		6.5	7.5		8.2	8.7	46.0		9.0	42.9	152
STD. DEVIATION (S)		2.1	1.2		2.2	1.4	8.4		1.2	0.9	20
($\bar{X} \div S$) 100 (%)		32.9	15.6		26.5	16.0	18.3		13.6	2.0	13

23
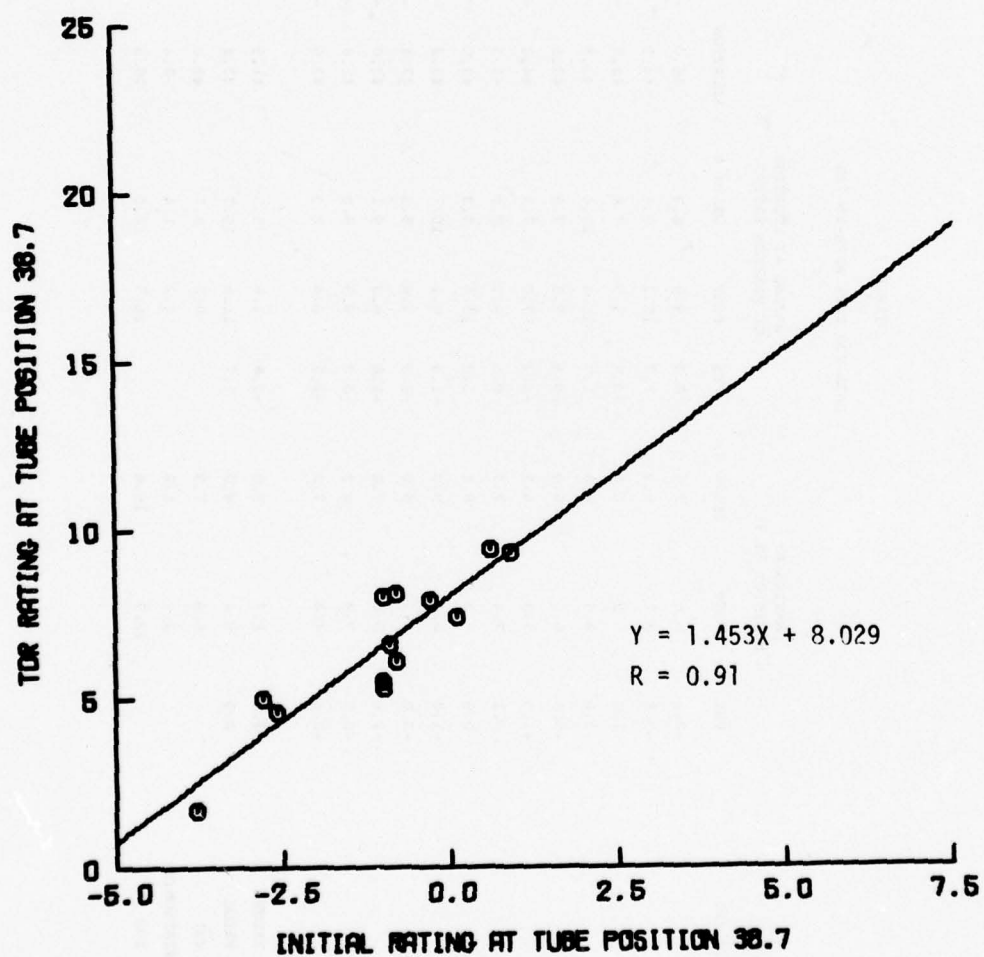
FIGURE 13. EFFECT OF INITIAL RATING ON RATING AT POSITION
38.7 (AFFB-16-73B)

24
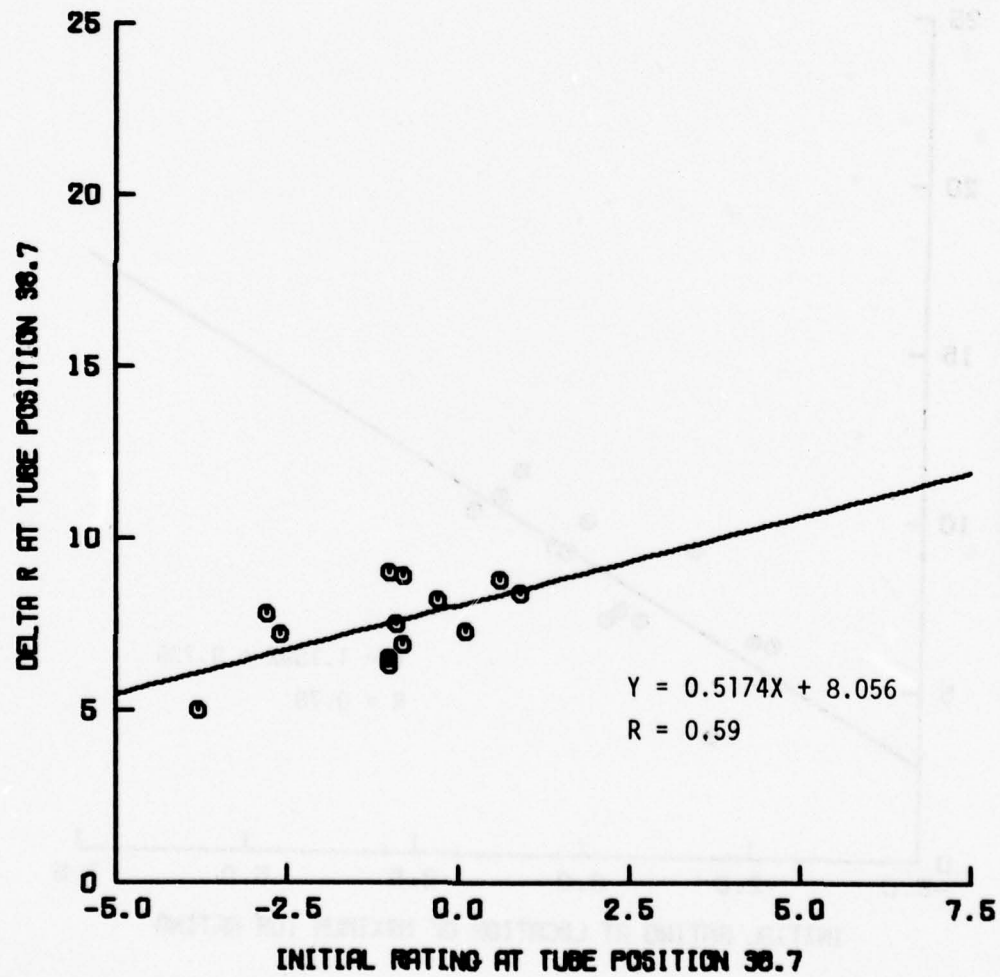
FIGURE 14. EFFECT OF INITIAL RATING ON DELTA R AT TUBE POSITION
38.7 (AFFB-16-73B)

25

$$Y = 1.189X + 8.735$$
$$R = 0.78$$

FIGURE 15. EFFECT OF INITIAL RATING ON MAXIMUM RATING (AFFB-16-73B)

26

FIGURE 16.   EFFECT OF INITIAL RATING ON DELTA R AT LOCATION OF
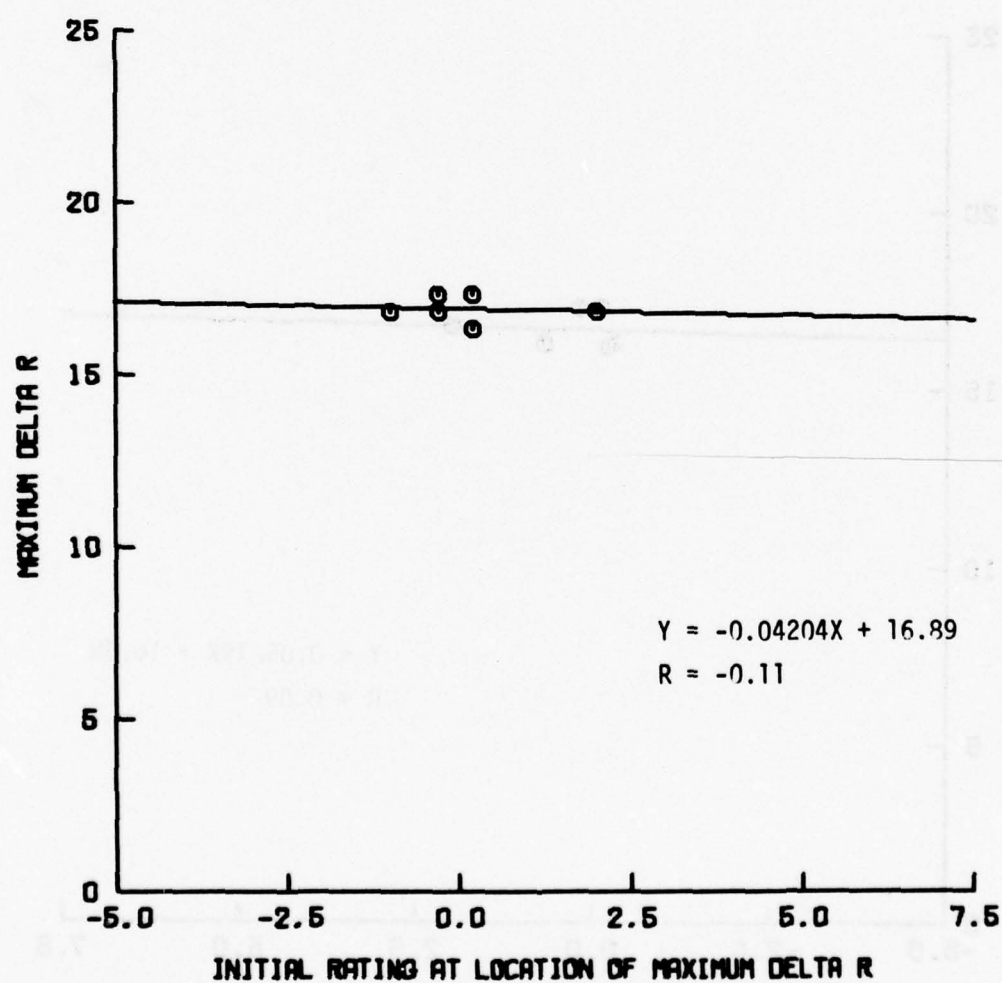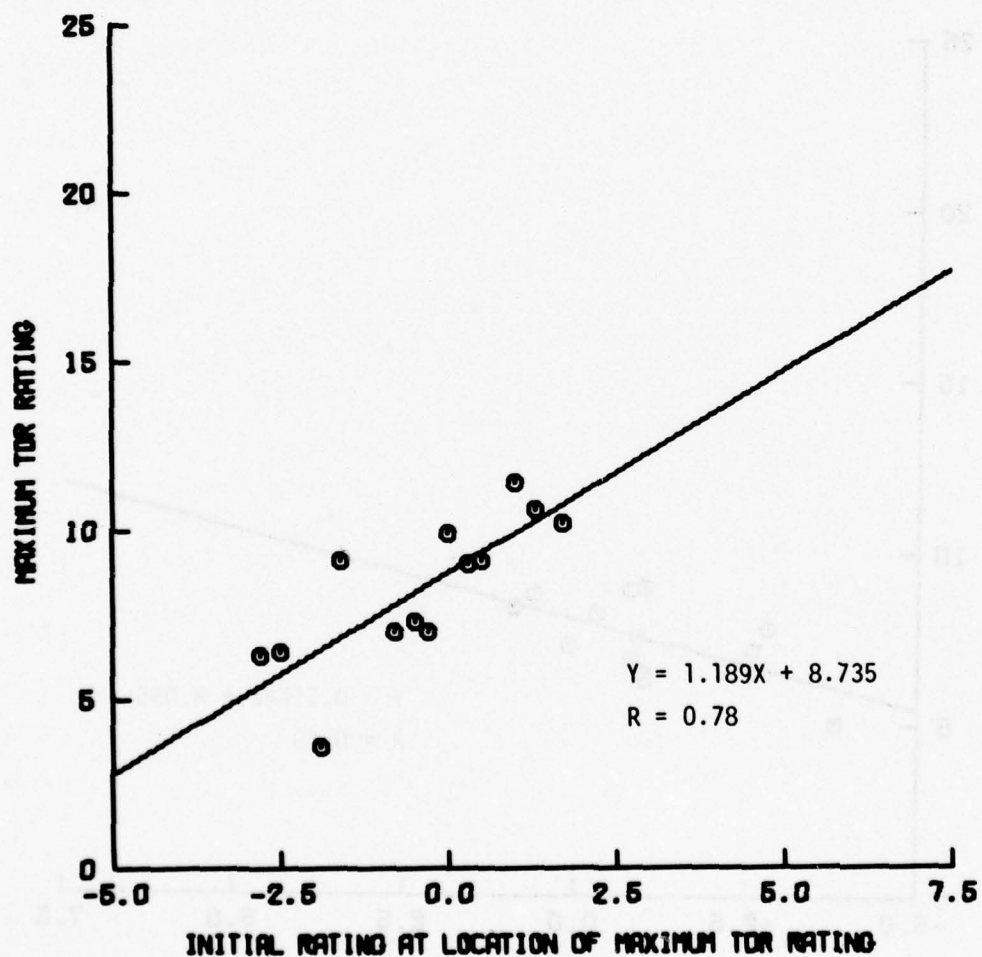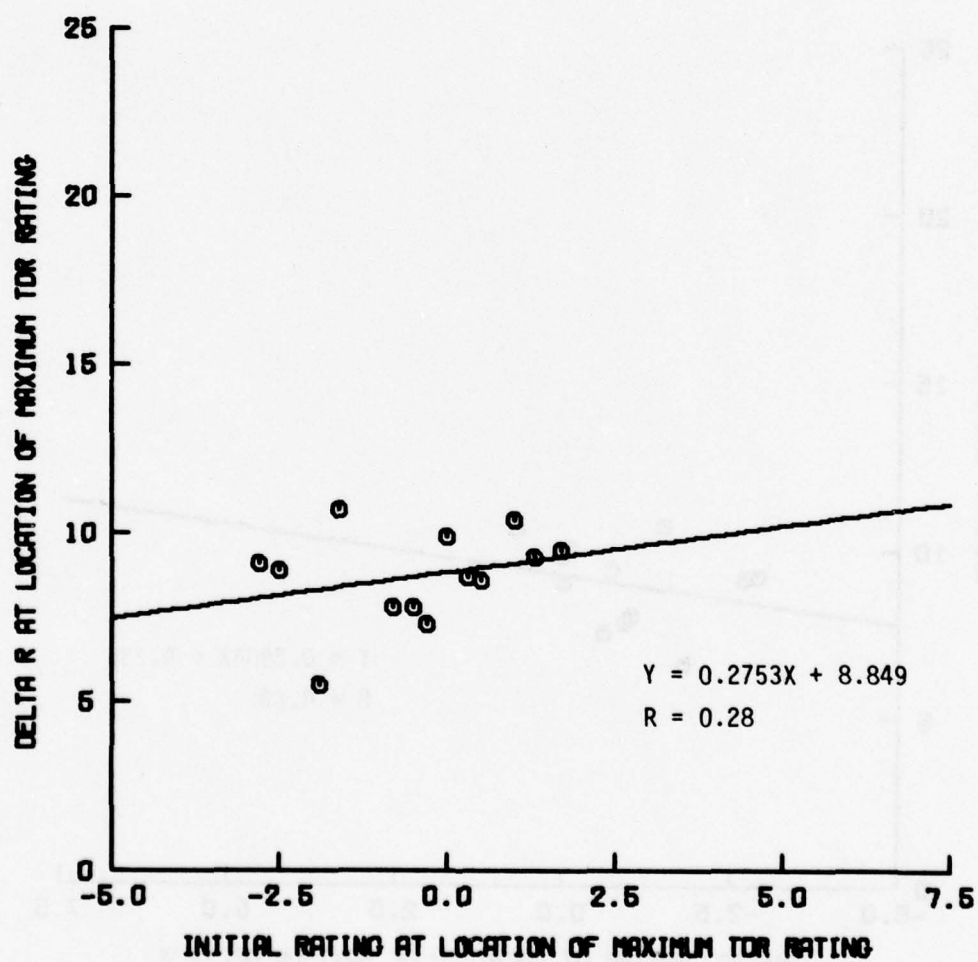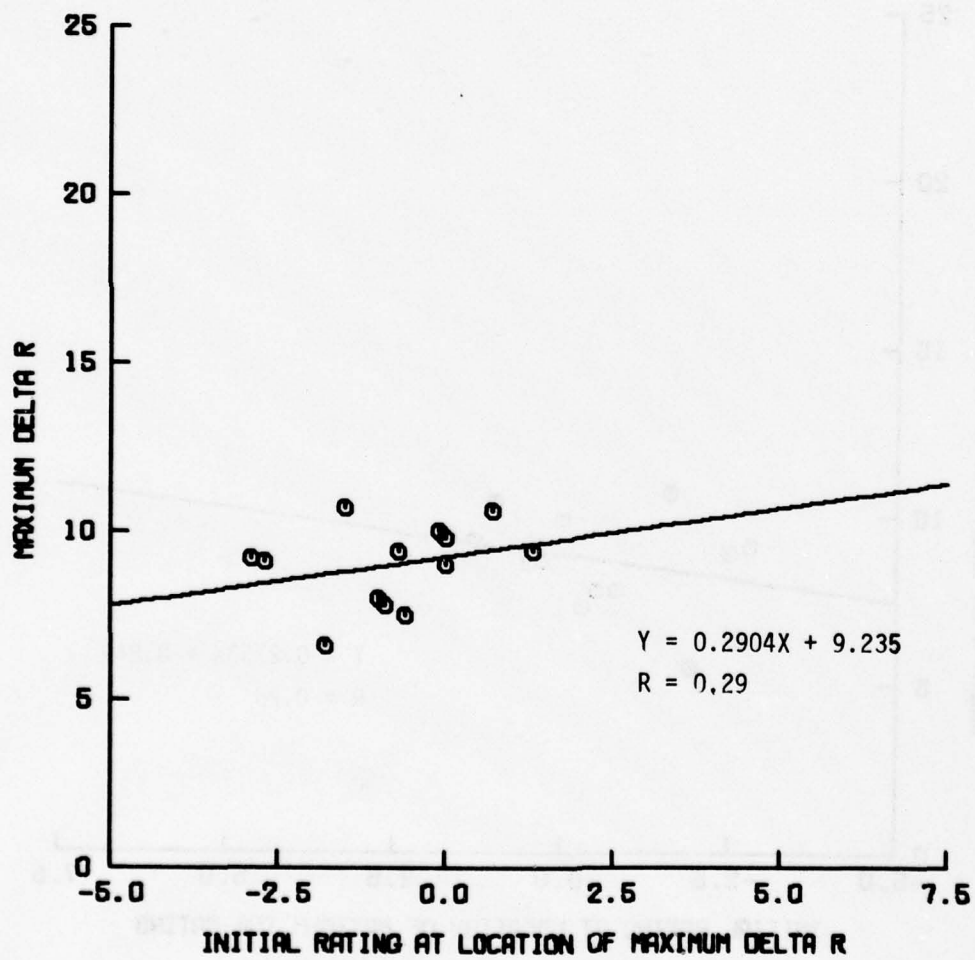MAXIMUM RATING (AFFB-16-73B)

27

FIGURE 17. EFFECT OF INITIAL RATING ON MAXIMUM DELTA R (AFFB-16-73B)

SECTION IV

RESULTS FROM PREVIOUS TESTING

1. MOTOR GAS

Tests were conducted on a 95-octane motor gas during January 1976 (Reference 2). Three of the tests were conducted at a test temperature of 260°C (500°F). The x-y plots of the TDR results were examined to determine if the initial ratings affected final ratings.

Fortunately, for the effort covered by this report, the initial ratings for one of the tubes was very low compared to the initial ratings of the two other tubes. The x-y plot of the rating results from all three tubes are shown in Figure 18. The wide variation in the initial ratings is evident in the Figure. It is also evident that the initial ratings affect the final ratings.

The same data are shown in Figure 19 with the initial-rating curves superimposed. The resulting closeness of fit of the after-test-rating curves indicates that initial ratings should be considered in arriving at a rating that is a valid measure of fuel performance in the JFTOT.

2. MARGINAL JP-7 FUEL

A marginal quality JP-7 type fuel was evaluated in the JFTOT as part of the continuing effort to develop a thermal oxidation stability test method for JP-7 (Reference 3). The JFTOT tests, each five hours long, were conducted on a fuel identified as 75-40A using a heated reservoir at a temperature of 149°C (300°F). The preheat time of the reservoir was varied over a range of 15 to 90 minutes and the maximum heat tube temperature was varied over a range of 283° to 390°C (500° to 734°F).
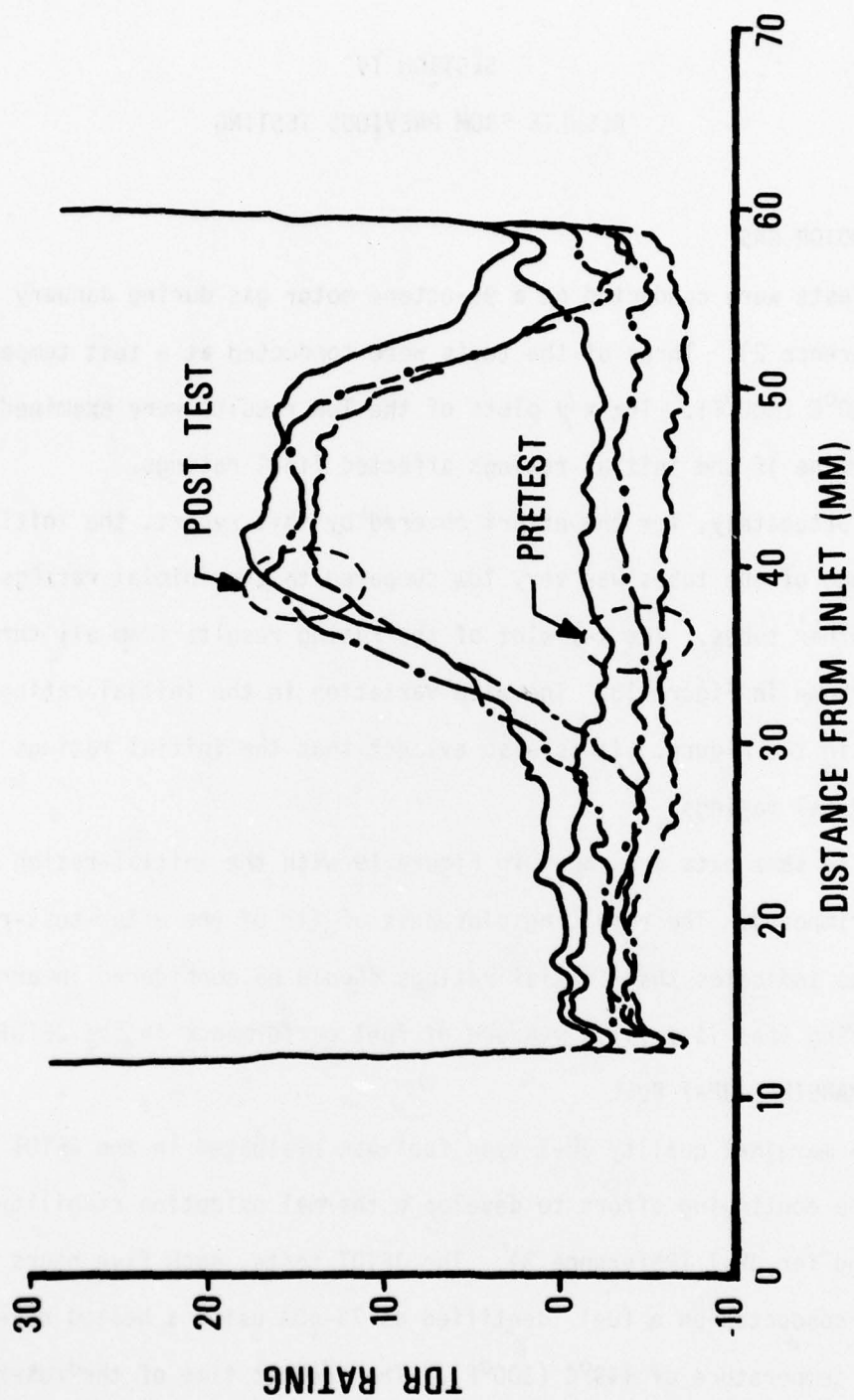
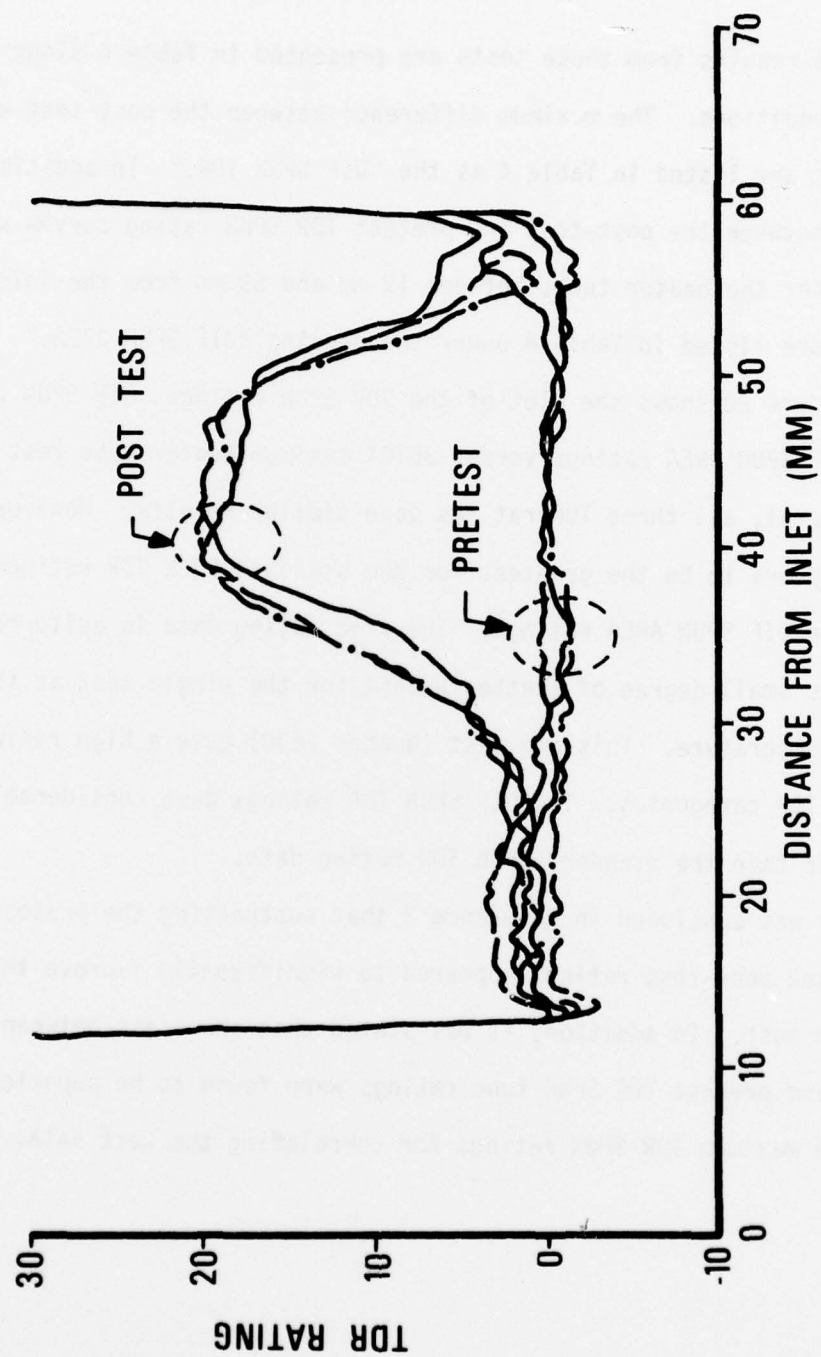FIGURE 18. TDR RATINGS FOR THREE TESTS CONDUCTED AT 260 °C (MOTOR GAS)

FIGURE 19. EFFECT OF INITIAL TDR RATINGS ON FINAL RATINGS

The results from these tests are presented in Table 4 along with the test conditions. The maximum difference between the post-test and pretest ratings are listed in Table 4 as the "DIF SPUN TDR." In addition, the areas between the post-test and pretest TDR SPUN rating curves were calculated for the heater tubes between 12 mm and 59 mm from the inlet. These areas are listed in Table 4 under the heading "DIF SPUN AREA."

Figure 20 shows the plot of the TDR SPUN ratings, DIF SPUN ratings, and the DIF SPUN AREA ratings versus JFTOT maximum heater tube test temperature. In general, all three TDR ratings gave similar results. However, the scatter appears to be the greatest for the standard SPUN TDR ratings and least for the DIF SPUN AREA ratings. The area rating data is quite remarkable for its small degree of scatter except for the single test at the 343°C test temperature. This one test (Number 2630) gave a high rating in all three TDR categories. The DIF SPUN TDR ratings gave considerable less scatter than the standard SPUN TDR rating data.

It was concluded in Reference 3 that subtracting the pretest TDR ratings from the post-test ratings appeared to significantly improve the repeatability of the test. In addition, it was stated that the areas between the post-test and pretest TDR SPUN tube ratings were found to be superior to the simple maximum TDR SPUN ratings for correlating the test data.

TABLE 4

JFTOT TEST DATA FOR A MARGINAL QUALITY JP-7 FUEL 75-40A

Test No.	Preheat Time (Min)	Heater Tube Rating Visual	Heater Tube Rating SPUN TDR	Dif. SPUN TDR	DIF. SPUN Area*	Test Temp (°C)
2623	20	1	6.5	6.5	180.	370
2624	60	1+	7.5	9.0	214.	370
2625	90	1	5.5	7.0	202.	370
2626	15	1	5.5	5	106.	316
2628	17	1	1.0	0.0	0.0	288
2629	16	1	1.5	3.5	92.	316
2630	19	1	7.0	8.0	312.	343
2632	60	1	0.5	3.0	83.	316
2633	60	1	4.0	6.5	192.	370
2637	20	1+	7.5	9.5	268.	390

* Area - Calculated using X-Y plots of SPUN TDR readings before and after tests. Units of area are TDR - mm
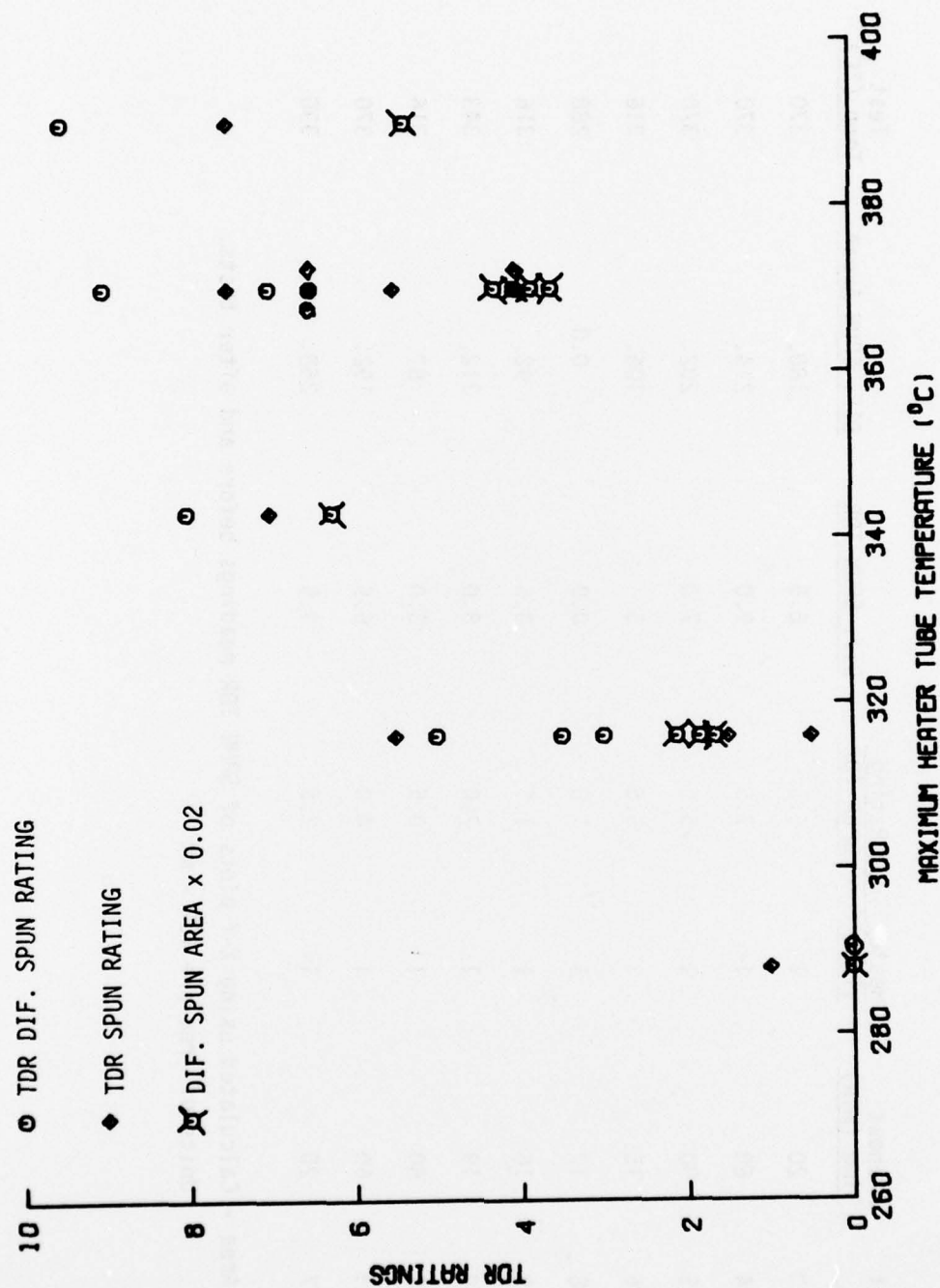
33

FIGURE 20. COMPARISON OF THREE TDR RATING METHODS

34

SECTION V

DISCUSSION OF RESULTS

The data accumulated for the three fuels used in conducting the test program to determine the effect of initial JFTOT tube ratings are summarized in Table 5. Examination of the data reveals that the use of delta R values significantly improves the data in five of the six cases and the values obtained for the sixth case are very close. In general, the data indicates that the best data is obtained by using maximum delta R values. The use of areas does not produce an improvement in the data as was indicated for the JP-7 fuel tested in previous program (Reference 3).

Examination of the summary data implies that the quality of the results would not decrease greatly by simply using the delta R values at a location of 38.7 mm from the inlet. This approach would greatly expedite the rating process. However, furthur examination of the data reveals that this con- clusion stems from the fact that the location of the peak in the post-test deposit rating curve for each of the fuels is close to the 38.7 mm position. Past experience indicates that the peak occurs at widely varying locations as a function of fuel type, crude source, processing, test temperature, etc., making it impractical to only rate tubes at the 38.7 mm location.

While it is admitted that the simple method of subtracting the pretest rating from the post-test rating is not the most accurate approach, this approach does have advantages. The only additional effort required is the prerating of each tube at selected locations along the tube axis. The operator then determines the maximum difference between the pretest and post- test ratings. However, use of the TDR in the manner described would require

TABLE 5

SUMMARY OF DATA

Parameter	Survey 12			Fuel Tested					
				AFFB-16-73A			AFFB-16-73B		
	$\overline{X}$	S	%	$\overline{X}$	S	%	$\overline{X}$	S	%
Rating at 38.7	13.7	3.9	28.7	15.5	1.0	6.2	6.5	2.1	32.9
Delta R at 38.7	13.0	2.7	21.1	15.7	0.7	4.3	7.5	1.2	15.6
Maximum Rating	14.7	3.8	25.8	17.2	1.0	5.7	8.2	2.2	26.5
Delta R at Location of Maximum Rating	12.7	3.3	26.1	16.7	0.5	3.1	8.7	1.4	16.0
Location of Maximum Rating	39.7	3.7	9.3	43.2	1.2	2.7	46.0	8.4	18.3
Maximum Delta R	13.5	2.9	21.8	16.9	0.4	2.2	9.0	1.2	13.6
Location of Maximum Delta R	39.2	1.7	4.2	42.7	0.8	1.8	42.9	0.9	2.0
Area Between Curves	240	56	23	343	41	12	152	20	13

that the scale be recalibrated. Tubes with ratings less than one cannot
currently be rated on the TDR. A possible solution is to make calibration
tubes that currently rate zero on the scale rate 10 instead.

Even though the data presented indicates that a significant improvement
is possible using the rating technique described, it is not suggested that
this approach is necessary for all situations. However, test results using
JP-7 as the test fuel indicate that if the JFTOT is to be used for JP-7
specification testing it may be necessary to use the TDR to rate the tubes.
Lack of sufficient deposit formation prevents the use of the Visual rating
technique. The TDR can detect these low-level deposits but the selection of
a low pass/fail criterion apparently will be required. That this approach
to rating tubes used in JP-7 testing will require consideration of the pretest
ratings of the JFTOT tubes is made clear by examining the data collected by
AFAPL during the testing of the JP-7 identified as WA-10 during Phase 2 of the
Coordinating Research Council program to evaluate the use of a heated JFTOT
reservoir. Ten out of 14 tubes had post-test ratings that were less than
zero on the TDR. These ten tubes had pretest ratings between -4.0 and -8.2.

SECTION VI
CONCLUSIONS

1. A method is needed to account for the effect of pretest TDR ratings on post-test ratings. This need is greatest at low pass/fail criterion as may be required for JP-7.

2. The simple method of subtracting pretest ratings from post-test ratings significantly improves the results.

3. The maximum change in the TDR rating for a given tube gave the best results for the four approaches evaluated.

4. Use of the subtraction technique would require a different calibration technique for the TDR.

5. Reducing the acceptable range of the pretest TDR ratings to a low level would eliminate the need to correct the ratings. However, a significant increase in the cost of the tubes would probably occur.

SECTION VII

RECOMMENDATIONS

1. The maximum change in TDR ratings should be used when greater
accuracy of TDR ratings is desired.

2. The method used to calibrate the TDR should be changed to enable
pretest rating of JFTOT tubes that rate below the bottom end of the
current meter scale.

REFERENCES

1. Capt. J. C. Ford, R. P. Bradley, and L. C. Angello, <u>JP-4 Fuel Thermal Stability Survey</u>, Air Force Aero Propulsion Laboratory Technical Report AFAPL-TR-73-27, June 1973.

2. R. P. Bradley, <u>Evaluation of Motor Gas in the Jet Fuel Thermal Oxidation Tester</u>, Air Force Aero Propulsion Laboratory Technical Report, to be published.

3. Royce P. Bradley and Charles R. Martel, <u>Results of Tests Using a Marginal JP-7 Fuel With a Modified JFTOT</u>, Air Force Aero Propulsion Laboratory Technical Memorandum AFAPL-SFF-TM-76-20, August 1976.

APPENDIX A

AFFB-16-73 Fuel Analysis

AFFB-16-73 FUEL ANALYSIS

	MIL-T-5624H	TEST RESULTS
Gravity, °API	45-57	56.1
Distillation, °F		
IBP	--	140°F
10% Evaporated (Min)	--	212°F
20% Evaporated (Min)	290°F	233°F
50% Evaporated (Min)	370°F	289°F
90% Evaporated (Min)	470°F	434°F
FBP	--	478°F
Residue, % (Max)	1.5 Max	1.0
Loss, % (Max)	1.5 Max	1.0
Flash Point, °F	2.0-3.0 RVP	--
Freezing Point, °F (Max)	-72°F	Below -72°F
Viscosity at -30°F, CS	--	--
Aniline Point, °F	--	141°F
Aniline Gravity Constant (Min)	5,250	7,910
Sulfur, Wt % (Max)	.40	.019
Mercaptan Sulfur, Wt % (Max)	.001	.000
Aromatics, Vol % (Max)	25.0	9.6
Olefins, Vol % (Max)	5.0	1.1
Existant Gum, Mg/100 Ml (Max)	7.0	1.4
Smoke Vol Index (Min)	52.0	64.7